

# Radio-frequency catheter cure of re-entrant supraventricular tachycardias: Report of the first experience in Hawaii

Edward N Shen MD

*Other than atrial fibrillation-flutter, the majority of supraventricular tachyarrhythmias involve either a macro-re-entry circuit utilizing an atrioventricular (AV) accessory pathway or a micro-re-entry circuit inside or around the AV node. The traditional form of therapy has been medical, with suppression by antiarrhythmic agents, most of which carry a heavy side-effect profile. The established alternative for medical therapy has been surgery, with open-chest excisional ablation of the accessory pathway<sup>1</sup> or cryo-modification of the AV node<sup>2</sup>. Even though, as opposed to medical therapy, surgery promises cure, it requires thoracotomy and cardiopulmonary bypass with significant associated morbidity and even mortality, as well as high cost. Ten years ago, the technique of "fulguration" was first introduced, which involved the delivery of an electrical charge through specialized catheters<sup>3</sup>. Our first experience with this technique was reported in this Journal<sup>4</sup>. Unfortunately, despite being a much better tolerated curative procedure involving a very brief hospitalization, the use of high-energy direct current (DC) shocks is associated with a low but significant incidence of serious complications including cardiac perforation, hypotension, coronary artery spasm, and late occurrence of ventricular fibrillation<sup>5</sup>. Concerns about these potential complications have markedly limited the application of the catheter technique. In the past 2 years, adoption of radio-frequency (RF) current as the energy source has allowed the ablation to be performed in a very efficacious and much safer fashion<sup>6-9</sup>. We would like to report the first experience with this technique in Hawaii.*

## Case reports

**Case 1** — A 64-year-old retired man with paroxysmal rapid palpitations for 12 years had episodes that were typically associated with severe weakness, lasting up to 16 hours. He had a baseline right bundle branch block and his tachycardia was documented as having the same configuration, with a rate of 165 per minute. He had failed to respond to empiric drug

therapy with digoxin and propranolol. Electrophysiologic (EP) study demonstrated classic AV nodal re-entrant tachycardia (down slow, up fast). In the study, intravenous procainamide resulted in suppression of the induction of tachycardia. He responded to the agent clinically but developed lupus syndrome, requiring drug discontinuation.

Therefore, he underwent catheter modification of the AV node. RF current was delivered through an enlarged-tip electrode on a quadripolar electrode catheter at 40 volts in discrete applications of up to 30 seconds. The "anterior" approach was used, which allowed for selective ablation of the fast AV nodal pathway (Figure 1A). Post ablation, the patient had a prolongation of atrial-His (AH) interval (from 90 to 140 milliseconds) and PR interval (from 0.16 to 0.23 seconds) with no tachycardia inducible. There was no evidence of myocardial damage by electrocardiogram (EKG), cardiac enzymes and echocardiogram. The patient was discharged 2 days post-procedure and had no tachycardia recurrence on followup.

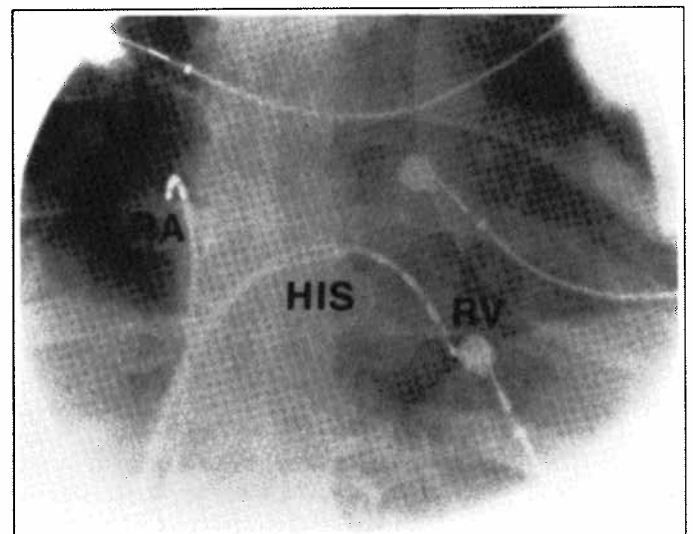


Figure 1A. Electrode catheter positions during electrophysiologic (EP) testing and radio-frequency (RF) catheter modification in Case 1. HIS = catheter in His position. RA = catheter in right atrium. RV = catheter in right ventricle. Note the larger tip of the catheter in the His position.

Associate Professor of Medicine  
John A Burns School of Medicine, University of Hawaii  
Director of Clinical Electrophysiology  
Straub Clinic and Hospital

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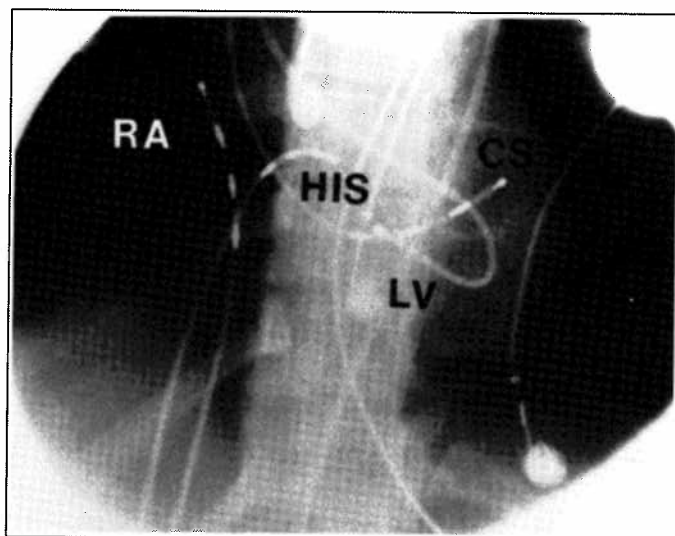


Figure 1B. Electrode catheter positions during EP testing and RF catheter ablation in Case 2. CS = catheter in coronary sinus. HIS = catheter in His position. RA = catheter in right atrium. LV = catheter in left ventricle.

**Case 2** — A 30-year-old housewife had had rapid palpitations since age 22. The average duration of her palpitations was 30 minutes. 12-lead EKG demonstrated Wolff-Parkinson-White (WPW) syndrome with suggestion of a posteroseptal AV accessory pathway (negative delta waves V1, III, aVF, positive delta waves V2-V6, I and aVL). Baseline EP study localized the accessory pathway at the ostium of the coronary sinus. The accessory pathway effective refractory period was 280 milliseconds (shortening to 240 milliseconds post isoproterenol). Classic AV reciprocating tachycardia (down AV node, up accessory pathway) was inducible, with rate of 200 per minute. Repeat testing on oral moricizine demonstrated complete blockage of the accessory pathway with no tachycardia inducible. However, the patient developed mild neurological side effects on the agent. For personal reasons she wanted to be drug free.

She underwent ablation of the accessory pathway. RF energy was applied at 60 volts for up to 30 seconds through the same catheter as described in the previous case. Initial application of the energy in the right atrium above the ostium of the coronary sinus was unsuccessful, resulting only in transient conduction loss through the accessory pathway.

Subsequently, the left ventricular approach was used. The catheter was prolapsed across the aortic valve and the tip was placed under the mitral valve leaflet on the mitral annulus, close to the posterior edge of the septum (Figure 1B). Application of RF energy here readily resulted in persistent loss of preexcitation. Again, post procedure, there was no evidence of myocardial damage by EKG, cardiac enzymes and echocardiogram. The patient was discharged 2 days post-procedure. There was no tachycardia recurrence on followup.

**Case 3 to 6** (See Table 1) — These cases involved 3 AV nodal modifications and one left lateral accessory pathway ablation, all successful.

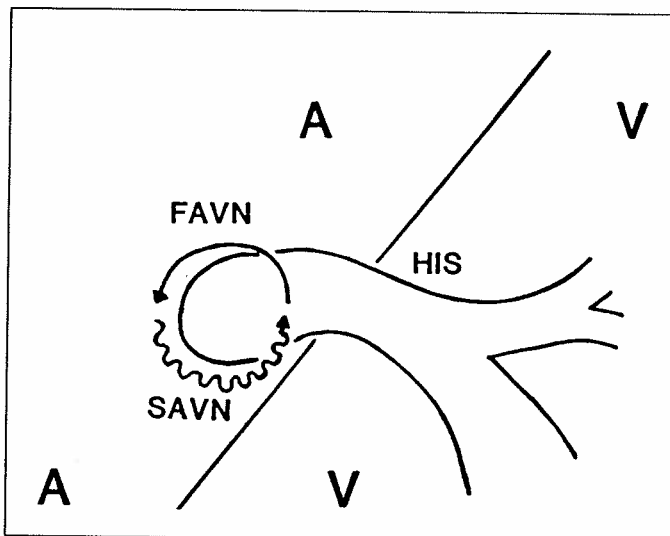


Figure 2A. Mechanism of atrioventricular (AV) nodal reentrant tachycardia. A = atrium, V = ventricle, FAVN = fast AV nodal pathway, SAVN = slow AV nodal pathway.

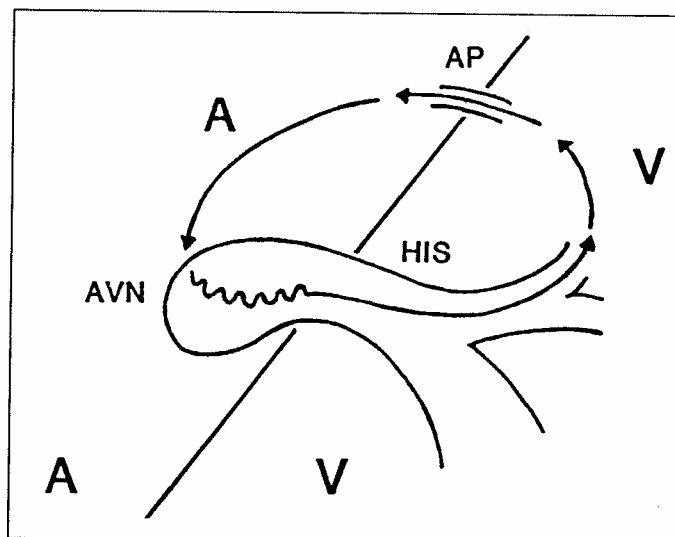


Figure 2B. Mechanism of orthodromic AV reciprocating tachycardia. A = atrium, AP = accessory pathway, AVN = AV node, V = ventricle.

## Discussion

### Mechanism

Cases 1 and 2 typify the majority of patients with problematic supraventricular tachycardias. In both patients, the tachycardia mechanism is re-entry or circus movement. During AV nodal re-entrant tachycardia, the circuit is inside or around the AV node. It involves antegrade conduction down a slow pathway and retrograde conduction up a fast pathway, both appearing to be anatomically distinct entities, with the fast pathway having a more superior (anterior) location around the node (Figure 2A). In orthodromic AV reciprocating tachycardia with WPW syndrome, the circuit entails antegrade conduction down the normal AV conduction system, across the

intervening ventricular myocardium, retrograde conduction up the accessory pathway, and across the intervening atrium (Figure 2B). The purpose of drugs or ablation therapy (surgical, DC current, RF current) is to interrupt the re-entrant circuit pharmacologically or physically.

### Technique

The diagnostic portion of the procedure first requires intracardiac placement of 3 quadripolar electrode catheters, introduced through right or left femoral vein under local anesthesia and positioned in the right ventricular apex, the His position (across the tricuspid valve) and high in the right atrium. Another quadripolar electrode catheter is inserted into the coronary sinus (large vein running in the AV sulcus posteriorly on the left), usually introduced via the right internal jugular vein. With these catheter positions intracardiac mapping is possible, from the right, left and septal atrium; stimulation is possible from both atria and the right ventricle. With programmed electrical stimulation, the tachycardia mechanism is defined and the location of any accessory pathway is precisely determined if present.

Once the mechanism has been defined, RF catheter ablation or modification can be performed. RF current is a form of electrical energy with frequency range of 150 kHz to 1.0 MHz (by comparison, audible sound is 20 to 20,000 Hz, ultrasound 1.0 MHz to 10MHz, microwave 1,000 MHz to 3,000 MHz). In a low-power, bipolar mode with a continuous unmodulated sinusoid waveform, the energy can be harnessed to cause well-demarcated coagulation necrosis of myocardial tissue without sparking, gas bubble formation or cellular destruction of blood elements (common problems with the fulguration form of catheter ablation, which uses a monophasic damped sinusoid "direct" current at much higher voltage). For our pur-

poses, the RF current is generated by an electrosurgical unit (model RFG-3C, Radionics, Burlington, Mass.) at a frequency of 350 kHz and given via a 7 French quadripolar catheter with a movable curve (Mansfield-Webster, Watertown, Mass.) The current is delivered between the large tip electrode on the catheter and an indifferent patch electrode on the patient's chest, usually at 40-60 volts. Because of the very high frequency, there is no neuromuscular stimulation and general anesthesia is not required.

For AV nodal re-entrant tachycardia, the key to success is modification or elimination of the fast or slow AV nodal pathway with preservation of overall AV conduction. Development of high grade or complete AV block is considered a complication.

There are 2 variations in the technique. In the "anterior" approach, the fast AV nodal pathway is ablated. The specialized catheter is first positioned across the tricuspid valve where a good His potential can be obtained. The catheter is then progressively pulled back until an atrial ventricular electrogram ratio of more than 1.0 is reached, and the His potential is barely recordable (Figure 1A). RF energy is then applied.

The endpoint of success is an increase of at least 50% in the AH interval, elimination or marked slowing of ventriculoatrial conduction and inability to induce tachycardia afterwards. The prolongation of AH interval (AV nodal conduction time) occurs because, with ablation of the fast AV nodal pathway, antegrade conduction through the node occurs only through the slow pathway. This was the protocol used in Cases 1, 4 and 5.

The slow AV nodal pathway, which has a more inferior (posterior) orientation, can be eliminated by using the "posterior" approach. In this technique, RF energy is applied to the

Table 1 — PATIENT PROFILE

Case	Age	Sex	Tachycardia Mechanism	Rate (beats/min)	Symptoms	Drugs Used	Heart Disease	RF Outcome	Complications	Recurrence
1	64	M	AVN	170	p,w	D,P,Pn	0	+,F	0	0
2	30	F	WPW	200	p	M'	0	+	0	0
3	58	F	AVN	175	c,p	D,Pn,V	0	+,S	DVT	0
4	37	F	AVN	250	d,l,p	D,P,V	0	+F	0	0
5	50	F	AVN	230	p,w	V	0	+,F	0	0
6	24	M	WPW	200	l,p,s	D,F,Pn Q,V	CM,M"	+	0	0

F = female M = male

AVN = atrioventricular (AV) nodal reentrant tachycardia.

WPW = Wolff-Parkinson-White syndrome with orthodromic AV reciprocating tachycardia.

c = chest pain, d = dyspnea, l = lightheadedness, p = palpitations, s = syncope, w = weakness

D = dispyramide, M' = moricizine, P = propranolol, Pn = procainamide, Q = quinidine, V = verapamil

+ = successful, - = unsuccessful, F = fast AV nodal pathway eliminated, S = slow AV nodal pathway eliminated

CM = cardiomyopathy, M" = malposition, DVT = deep vein thrombophlebitis

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right atrium between the His bundle location and the ostium of the coronary sinus. Since the fast pathway is not affected, the AH and PR intervals will not be changed. The endpoint of success is elimination of the dual AV nodal curves during programmed extrastimulus stimulation, as well as the inability to induce tachycardia. We have used this protocol in Case 3 and have found equal success with it.

For ablation of AV accessory pathways in the WPW syndrome, the location of the pathway is first defined by mapping of the atrial depolarization sequence during ventricular pacing and orthodromic tachycardia. Measurement of accessory pathway potential as a means of localization is helpful but too time consuming. We have found instead the shortest AV interval highly useful. For left free-wall pathways, the specialized catheter is first introduced through the femoral artery and advanced retrogradely through the aortic valve into the left ventricle. The large tip electrode is placed beneath the mitral leaflet and against the mitral annulus (the annulus is well outlined by the catheter in the coronary sinus). RF energy is applied at the location previously mapped, where a very short AV interval can be measured.

For right free wall and anteroseptal accessory pathways, right internal jugular venous access is generally used. The specialized catheter is advanced through the right atrium into the right ventricle and then curled up below the tricuspid valve with the tip electrode against the tricuspid annulus. The tricuspid annulus can be outlined by a wire placed in the right coronary artery.

There are 2 approaches to posteroseptal pathways, both described previously in Case 2. In our case, the left ventricular approach (Figure 1B) was successful, probably attesting to a very oblique orientation of the accessory pathway.

The endpoint of success is complete elimination of both antegrade and retrograde conduction through the accessory pathway with no tachycardia inducible afterwards. In our patients, there was complete loss of preexcitation with elimination of delta waves on the surface EKG, a change in the retrograde AV conduction sequence (with the earliest site of retrograde depolarization being the septal atrium, suggesting conduction only through the normal AV conduction system and not eccentrically through the accessory pathway), as well as non-inducibility of the tachycardia.

There is currently almost no experience with atrial flutter. However, since the majority of flutters involve a macro-reentry circuit in the right atrium with a zone of slow conduction in the low right atrium, this arrhythmia is potentially also amenable to RF catheter cure.

## Efficacy and Complications

The reported success rate in the literature has been 92 to 98%. In our experience with 6 patients so far, the technique has been uniformly successful.

For AV nodal modification and for ablation of posteroseptal AV accessory pathways, there is a reported low incidence of high grade AV block (about 1%). In the 2 largest series reported so far<sup>5,6</sup>, there have been less than 1% incidence of pericarditis, cardiac tamponade and myocardial infarction (one case each). The case of myocardial infarction reported occurred by inadvertent introduction of the catheter into the

circumflex artery rather than the aortic valve (a complication which can be avoided by an experienced catheterizer). In the one case of pericardial tamponade and the other case of pericarditis, the RF current was applied in a small branch of the coronary sinus. It appears that avoidance of delivery of RF energy inside the coronary sinus or its branches may eliminate these complications altogether.

In our experience, deep vein thrombophlebitis in the right leg from catheter insertion occurred in Case 3. This is a complication which may be seen infrequently during routine electrophysiologic studies (generally related to multiple catheter insertion into the same vein and prolonged duration of the procedure) and is not unique to the RF technique. It has now become our practice to give patients 3000 units of heparin intravenously at the beginning of the procedure and 1000 units every additional hour.

Theoretically, clinically significant thromboembolic events may occur whenever a catheter is placed in the arterial circulation. With accumulation of a larger experience worldwide, a low incidence of strokes (so far unreported) may come to light as a result of ablation of left-sided accessory pathways which requires arterial catheterization. This incidence may be minimized or eliminated by heparinization as well as by intermittent inspection of the ablation catheter tip for coagulum (chared). A coagulum is generally suspected when there is a rapid rise in measured impedance during the application of RF energy.

## A comparison

Even though similar efficacy is achievable through open-chest surgical procedures, the 5 to 10% incidence of morbidity (bleeding, infection, stroke, atelectasis, sternal dehiscence, Dressler's syndrome, etc, not considering chest pain which occurs in all) and prolonged recovery time will make surgery a much less attractive option.

Empiric antiarrhythmic therapy (unguided by EP testing) is, of course, noninvasive. However, even if an effective agent could be found by trial-and-error, the high frequency of side effects (20 to 50)% for most drugs) as well as the specter of life-threatening proarrhythmia would make this alternative also quite undesirable. Furthermore, the majority of the patients with supraventricular tachycardias tend to be young (for women, in the reproductive age). The prospect of facing 40 or 50 years of taking medications (up to 3 times a day) is unacceptable to many, even back in the dark ages when no other treatment was available.

Finally, what about expenses? The total charge for surgery is about \$50,000, for RF ablation about \$7,500. At first glance, the cost of generic verapamil (80 mg 3 times a day) at \$24.45 a month appears to be a real bargain. But taking it over a period of 40 years will need \$34,713 (assuming 5% a year inflation). Even if the patient has the foresight to stockpile 40 years' worth with one visit, it will still require \$11,736 (and storage space for 43,810 pills). Understandably, this does not include the cost of the occasional emergency room visit for breakthroughs (from noncompliance or otherwise). Furthermore, medical therapy is probably inappropriate for patients with WPW syndrome and "fast" accessory pathways, who are at risk for sudden death<sup>10,11</sup>.

### Conclusion

Radio-frequency catheter ablation is a highly successful, safe and relatively inexpensive technique which will revolutionize the treatment of re-entrant supraventricular tachyarrhythmias. It is quite probable that in the near future any patient with sustained supraventricular tachycardia may be admitted to hospital, undergo the diagnostic and RF catheter procedure the same day, and be discharged within 1 to 2 days without having to go through the rather unpleasant experience of diarrhea (quinidine), joint pains (procainamide), dry mouth (disopyramide), constipation (verapamil), or disturbing phone calls from a relative warning about sudden death (flecainide).

I can recall in my previous article on fulguration the comparison of the relationship between catheter ablation and surgery for arrhythmia (known as arrhythmia surgery) to that between percutaneous transluminal coronary angioplasty and coronary artery bypass surgery. This is actually quite invalid. As everyone knows, there is no cure for coronary artery disease.

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